THE PECULIAR VOLATILE COMPOSITION OF COMET C/2016 R2 (PANSTARRS)

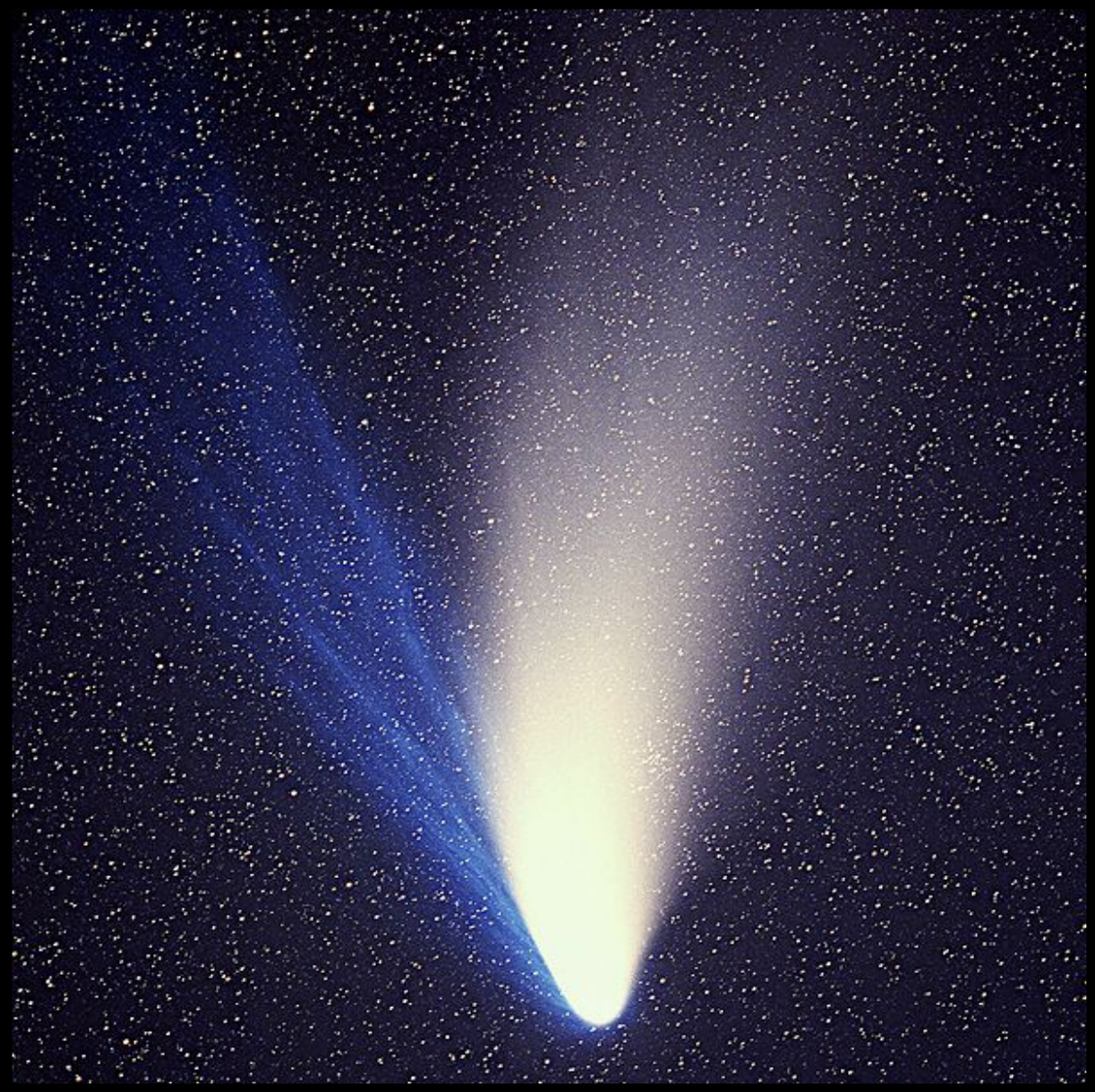
Adam McKay (NASA GSFC/USRA)

Michael DiSanti, Michael Kelley, Anita Cochran, Neil Dello Russo, Maria Womack, Kacper Wierzchos, Nicolas Biver, Martin Cordiner, Miguel De Val Borro, James Bauer, Olga Harrington Pinto, Boncho Bonev, Ronald Vervack, Jr., Erika Gibb, Nathan Roth, and Hideyo Kawakita

Carbon in the Solar System Workshop- April 26, 2018

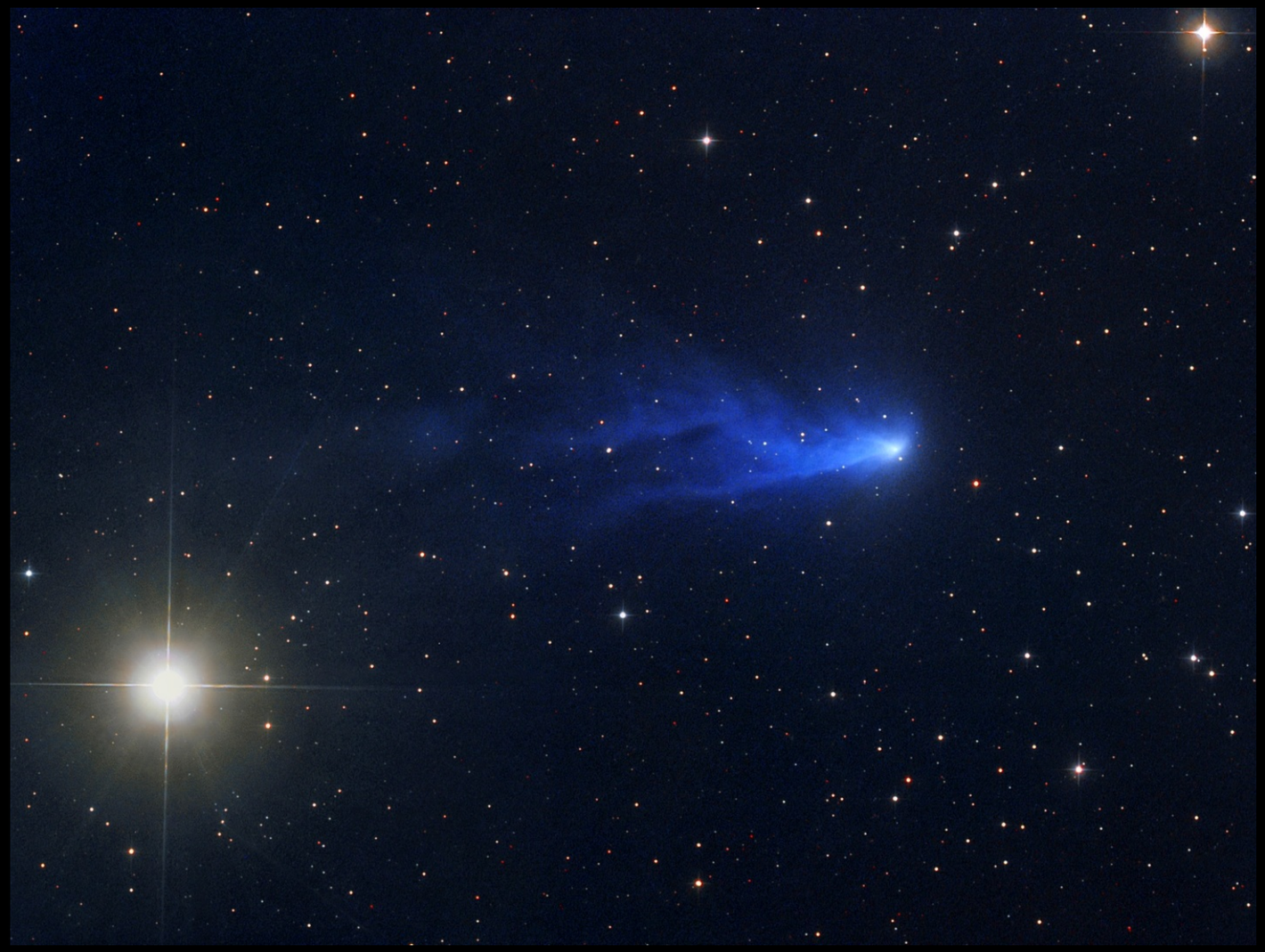
INTRODUCTION

- Cometary composition is among the most primitive in the Solar System
- “Comets are like cats, they have tails and they do precisely what they want.”- David Levy



C/1995 O1 (Hale-Bopp). Image Credit: E. Kolmhofer, H. Raab

MEET C/2016 R2 (PANSTARRS)



C/2016 R2 (PanSTARRS) on January 6, 2018. Image Credit: Michael Jäger

- Discovered September 7, 2016 by PanSTARRS survey
- Perihelion=2.6 AU in May 2018, orbital period ~ 20,000 years
- Predicted peak magnitude 10-11
- Not particularly noteworthy, until . . .

THAT'S ODD . . .

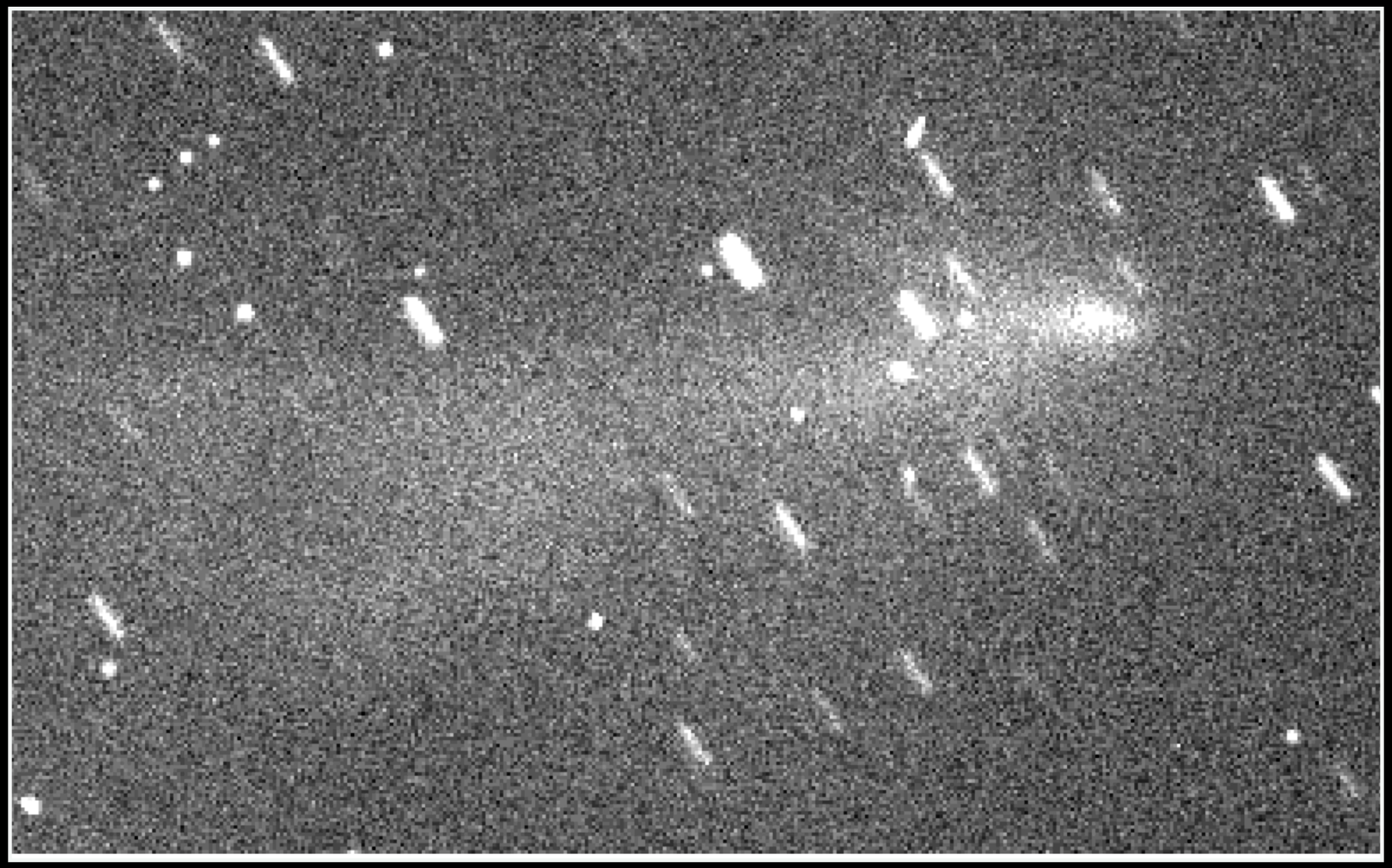
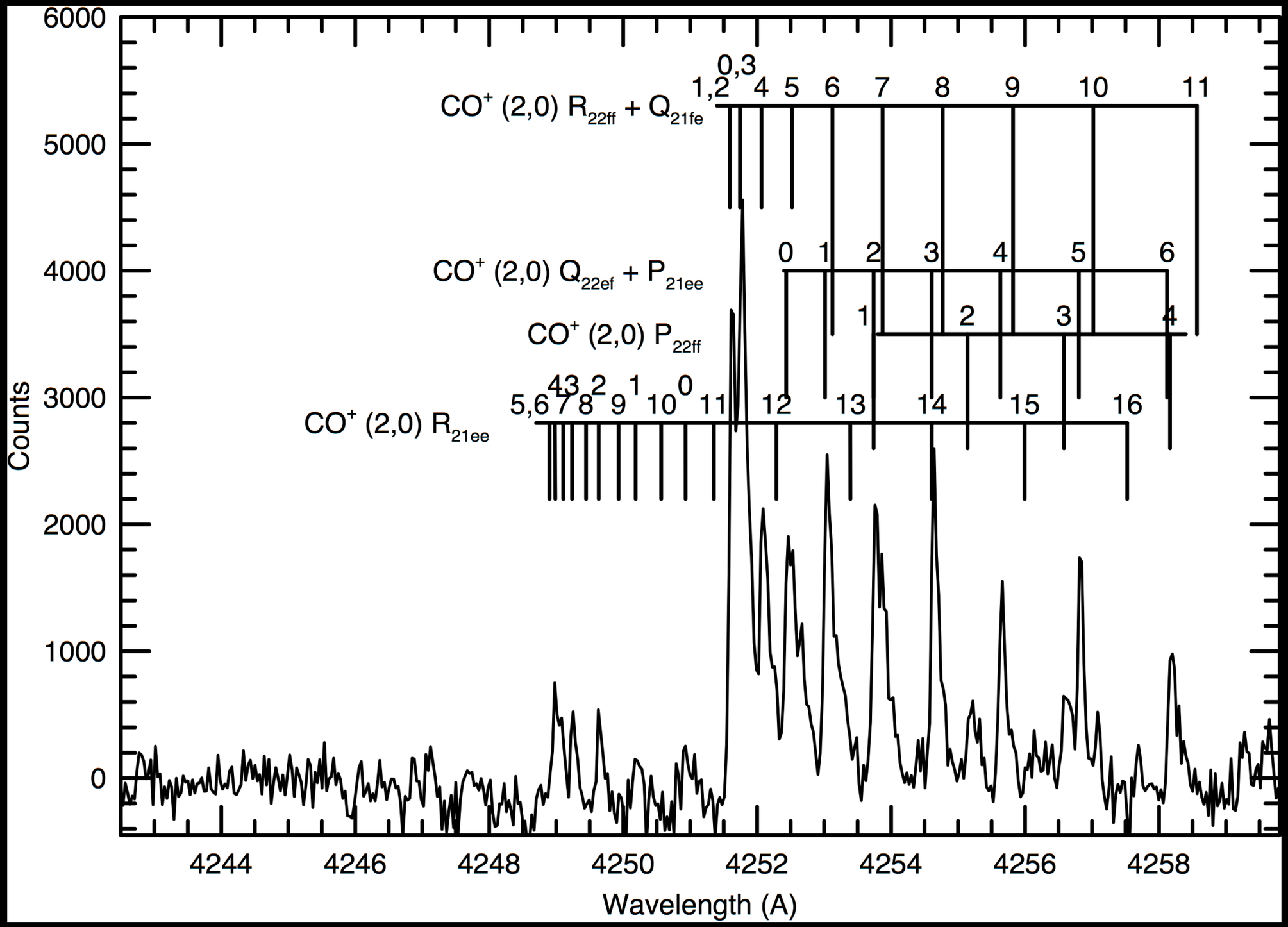


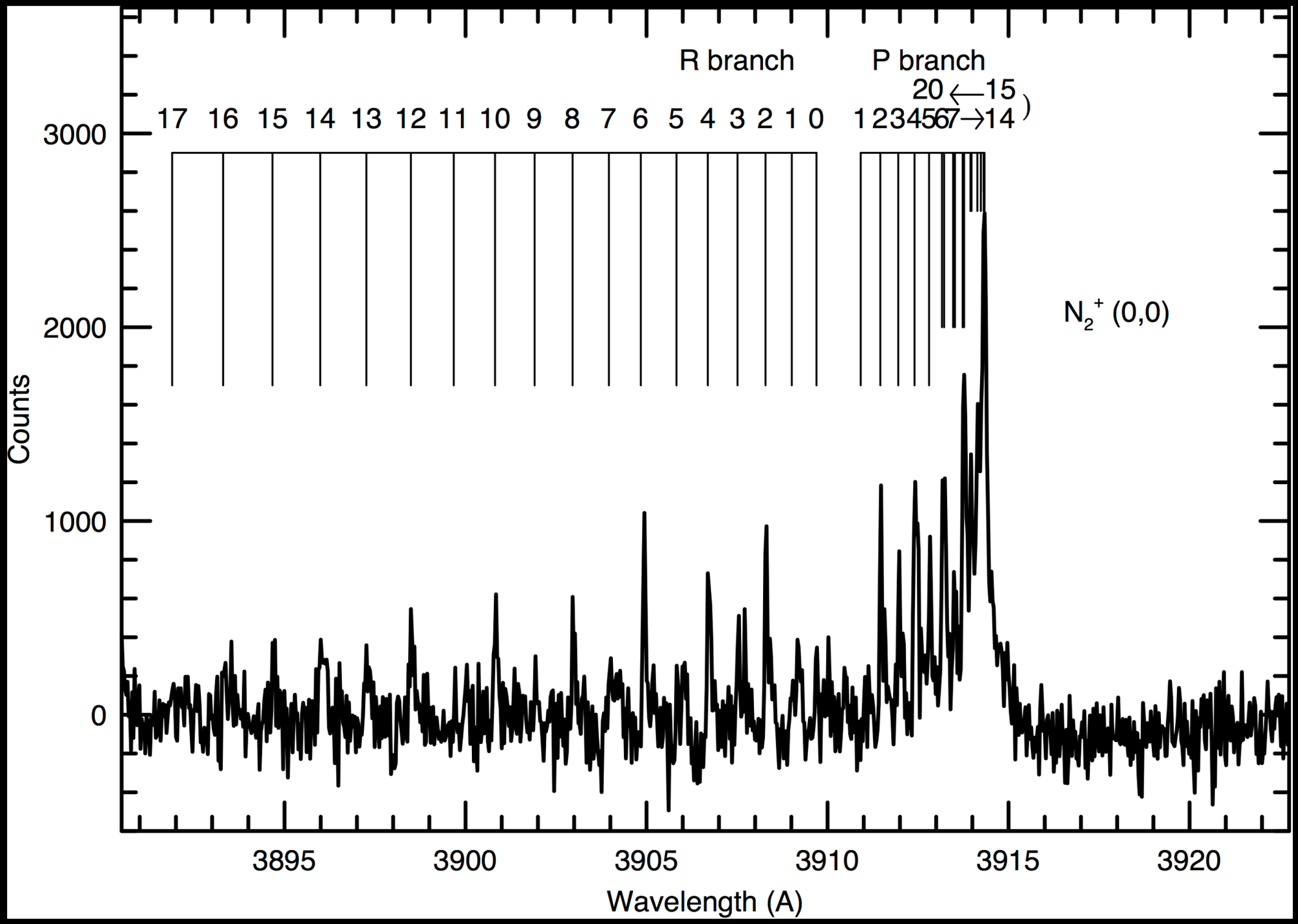
Image obtained in Hale-Bopp CN filter from
0.8-meter telescope at McDonald Observatory, UT
November 14, 2017 (Cochran and McKay 2018)

STRONG CO+ EMISSION



Cochran and McKay 2018

N_2^+ EMISSION!

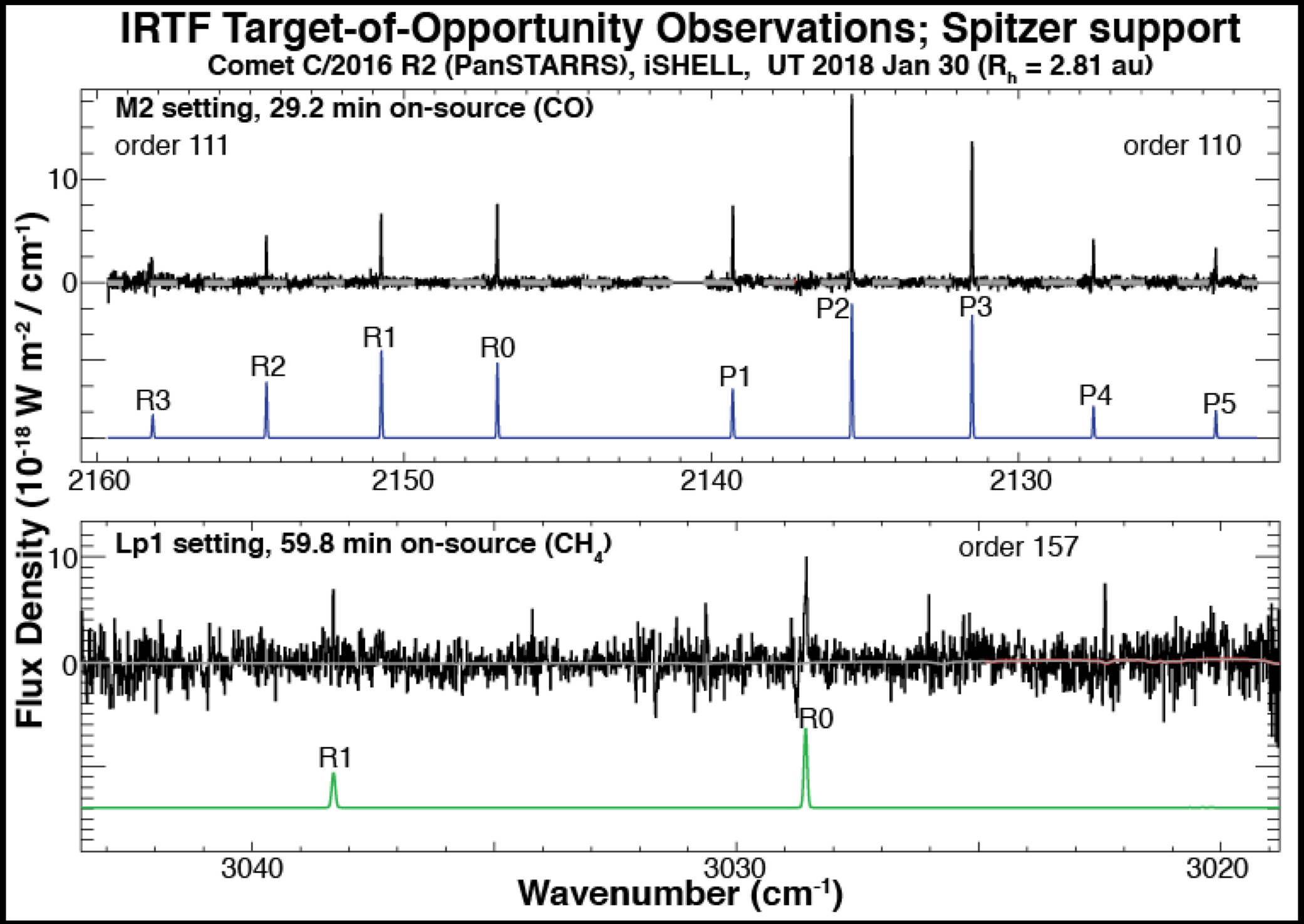


Cochran and McKay 2018

IMPLICATIONS-N_2/CO

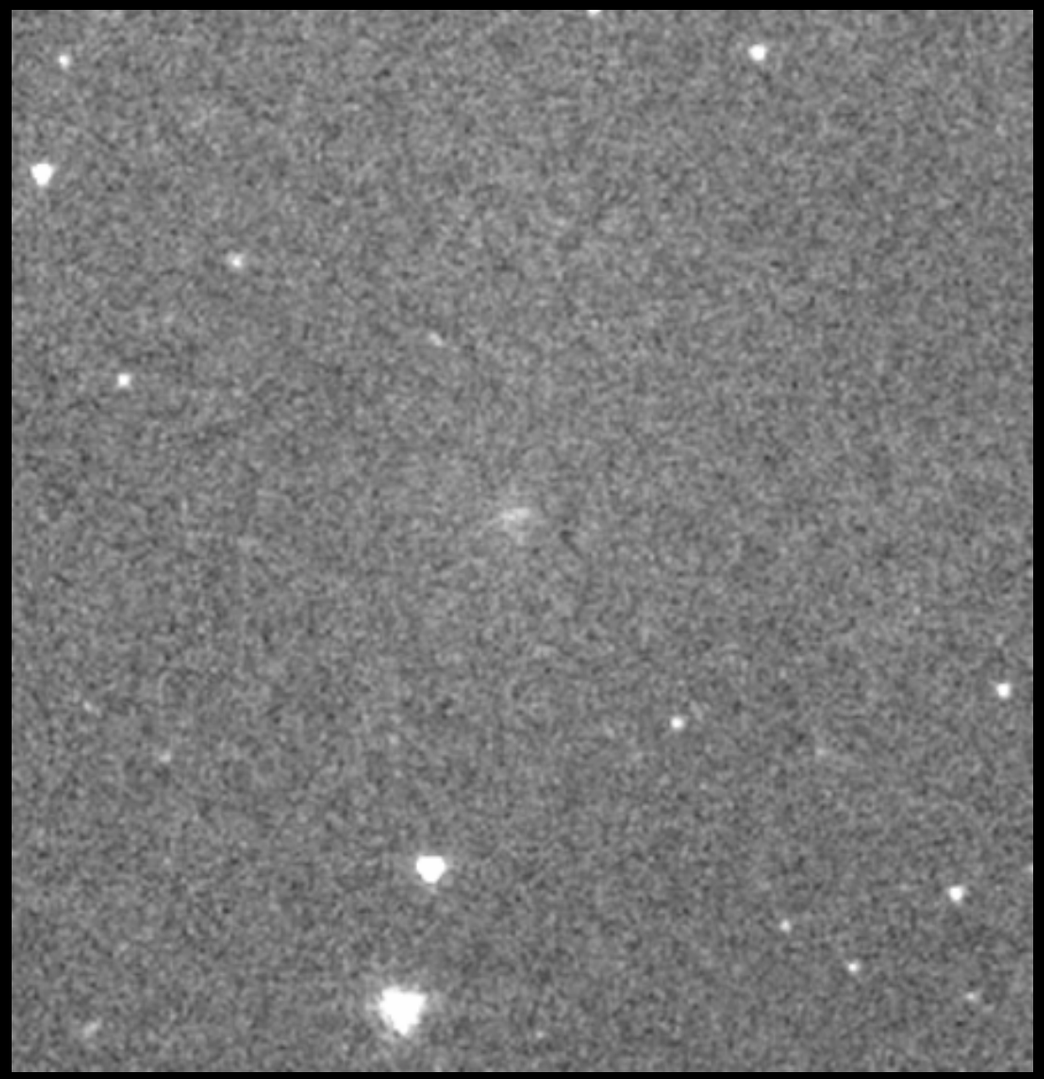
COMET	METHOD	N_2/CO	REFERENCE
C/2016 R2 (PANSTARRS)	N_2^+	0.06	COCHRAN AND MCKAY 2018
C/2002 VQ94 (LINEAR)	N_2^+	0.06	KORSUN ET AL. 2014
29P/SCHWASSMANN-WACHMANN 1	N_2^+	0.013	IVANOVA ET AL. 2016
122P/DE VICO	N_2^+	$< 3 \times 10^{-4}$	COCHRAN ET AL. 2000
C/1995 O1 (HALE-BOPP)	N_2^+	$< 6 \times 10^{-5}$	COCHRAN ET AL. 2000
67P/CHURYUMOV-GERASIMENKO	IN-SITU MASS SPECTROMETRY	5.7×10^{-3}	RUBIN ET AL. 2015
C/2001 Q4 (NEAT)	UV	<0.027	FELDMAN ET AL. 2015

ISHELL IRTF-CO AND CH_4



CO_2 WITH SPITZER

3.6 micron



Dust

4.5 micron

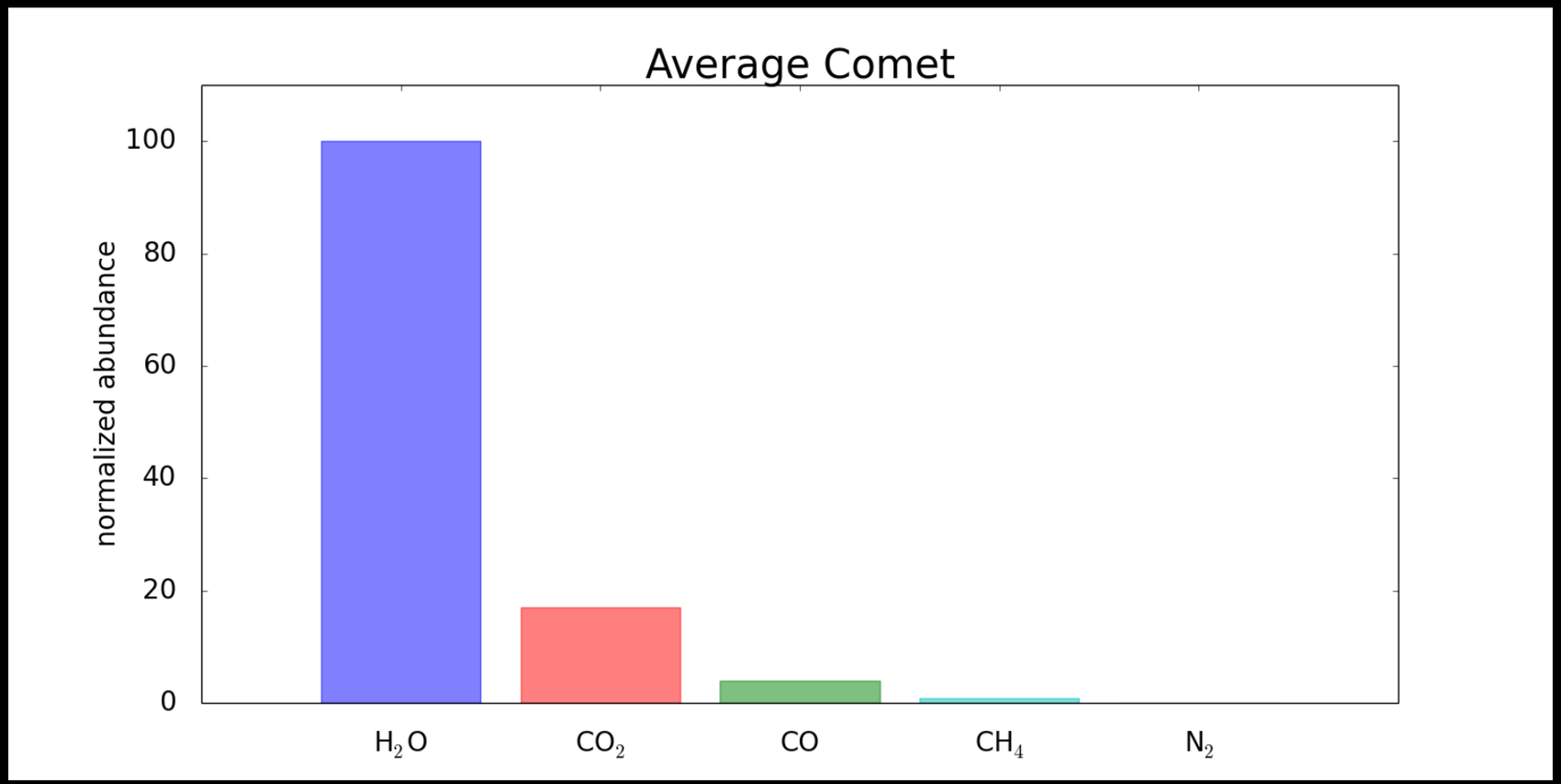
Dust+CO_2+CO

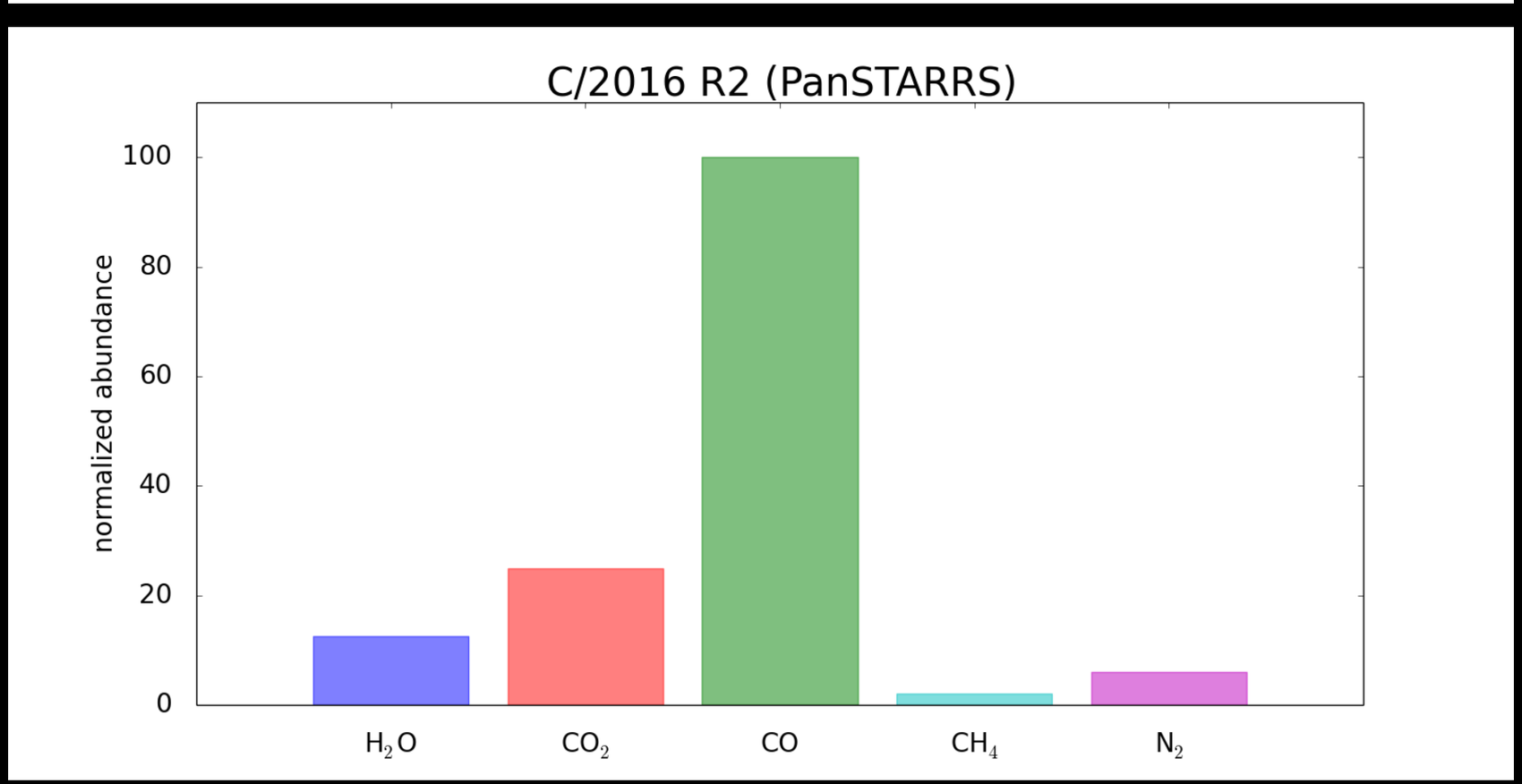
February 12, 2018

HOW DOES C/2016 R2 FIT IN THE COMPOSITIONAL TAXONOMY?

SPECIES	X/H_2O(%)	AVE X/H_2O (%)	X/CO(%)	AVE X/CO (%)
CO	~800	4.0±0.9	100	-
CH_4	~16	0.88±0.10	~2	22.0±5.5
C_2H_6	<1.52	0.63±0.10	< 0.19	15.8±4.4
H_2CO	<3.44	0.33±0.08	< 0.43	8.0±2.6
CH_3OH	<7.6	2.21±0.24	< 0.95	55.3±13.8
CO_2	~300	17±6	~25-50	425
N_2	~50	<<1?	~6	<1?
HCN*	<0.56	0.22±0.03	<0.07	5.5±1.4

*derived from sub-mm observations (Wierzchos and Womack submitted)


Average Comet
normalized abundance
100
80
60
40
20
0
H_2O
CO_2
CO
CH_4
N_2


C/2016 R2 (PanSTARRS)
normalized abundance
100
80
60
40
20
0
H_2O
CO_2
CO
CH_4
N_2

IMPLICATIONS

- R~ 3 AU, some of elevated CO/H_2O can be accounted for by the large heliocentric distance, but not two orders of magnitude
- Additionally, CH_4/CO and CO_2/CO should not be affected at 3 AU
- CO and N_2 most primitive molecular forms of carbon and nitrogen in the universe, very little chemical processing where C/2016 R2 formed?
- CO and N_2 also extremely volatile, suggesting C/2016 R2 must have formed in the very outer region of the disk
- C/2016 R2 is not dynamically new, it has been in the inner Solar System before, repeated heating has not depleted hyper-volatiles

IMPLICATIONS (CONTINUED)

- Assuming CO and CO_2 dominant volatile reservoirs for carbon, N_2 dominant volatile reservoir for nitrogen, then C/N ~ 10
- Twice Solar value, but lower than typical comets (~20)
- CO and CO_2 are dominant volatile reservoirs of oxygen, not H_2O! (though the presence of O_2 cannot be ruled out)
- Could C/2016 R2 have formed where C/O > 1, allowing most oxygen to be locked up in CO and CO_2 rather than H_2O?
- Dust composition unknown

FUTURE WORK

- Many more observations at optical, UV, IR, and sub-mm wavelengths!
- Finalize the analysis of Spitzer imaging, account for optical depth and other effects on iSHELL CO observations
- Gotta get the water!
- Stay tuned!

Acknowledgments: This work was supported by the NASA Postdoctoral Program, administered by the Universities Space Research Consortium.

SPECTROSCOPIC FOLLOWUP

- Tull Coude spectrograph at McDonald Observatory
- UT December 8-10, 2017
- R=3.1 AU
- $R \equiv \lambda/\Delta\lambda = 60{,}000$

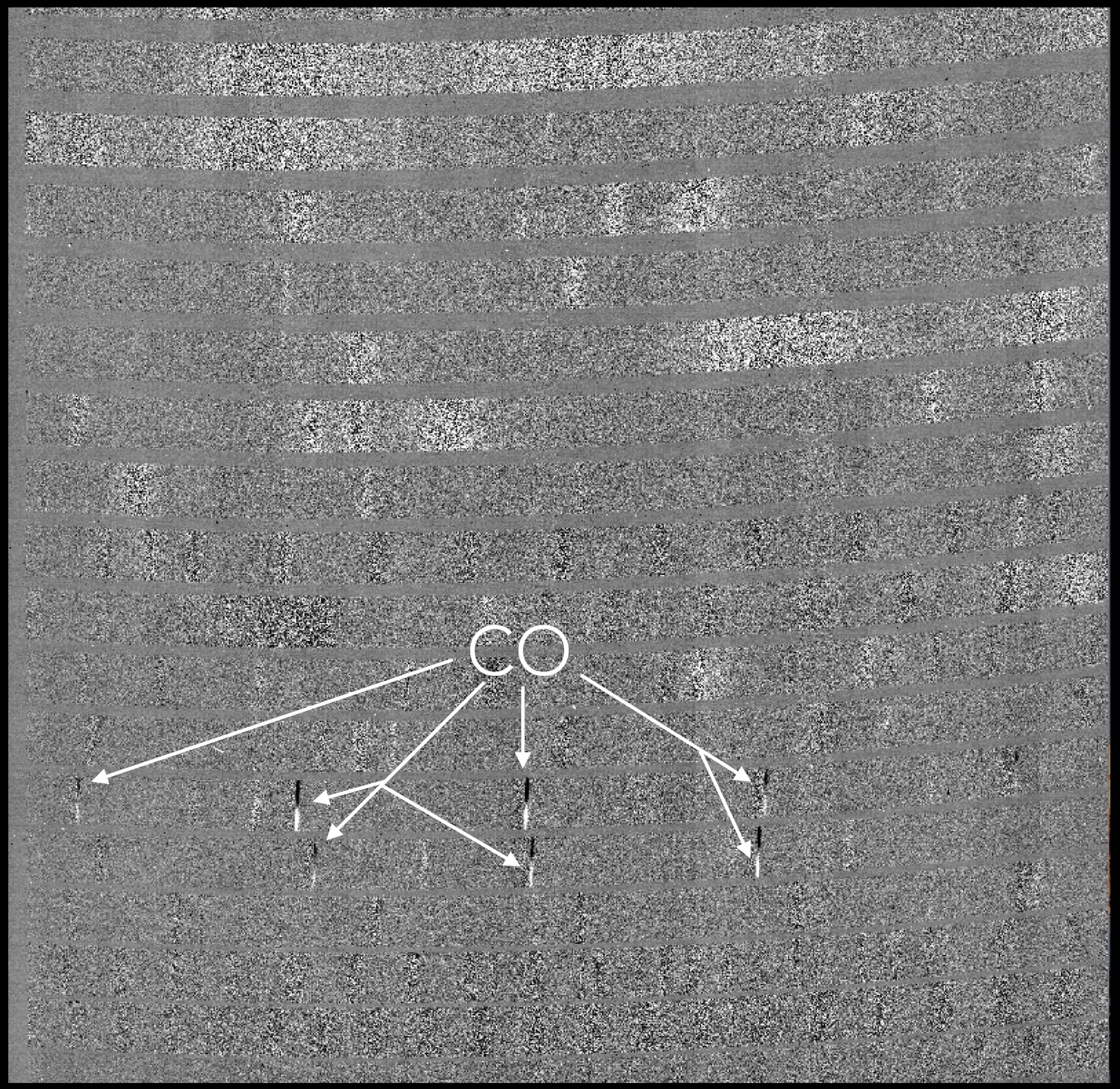
Image Credit: McDonald Observatory

IR SEARCH FOR CO AND OTHER VOLATILES

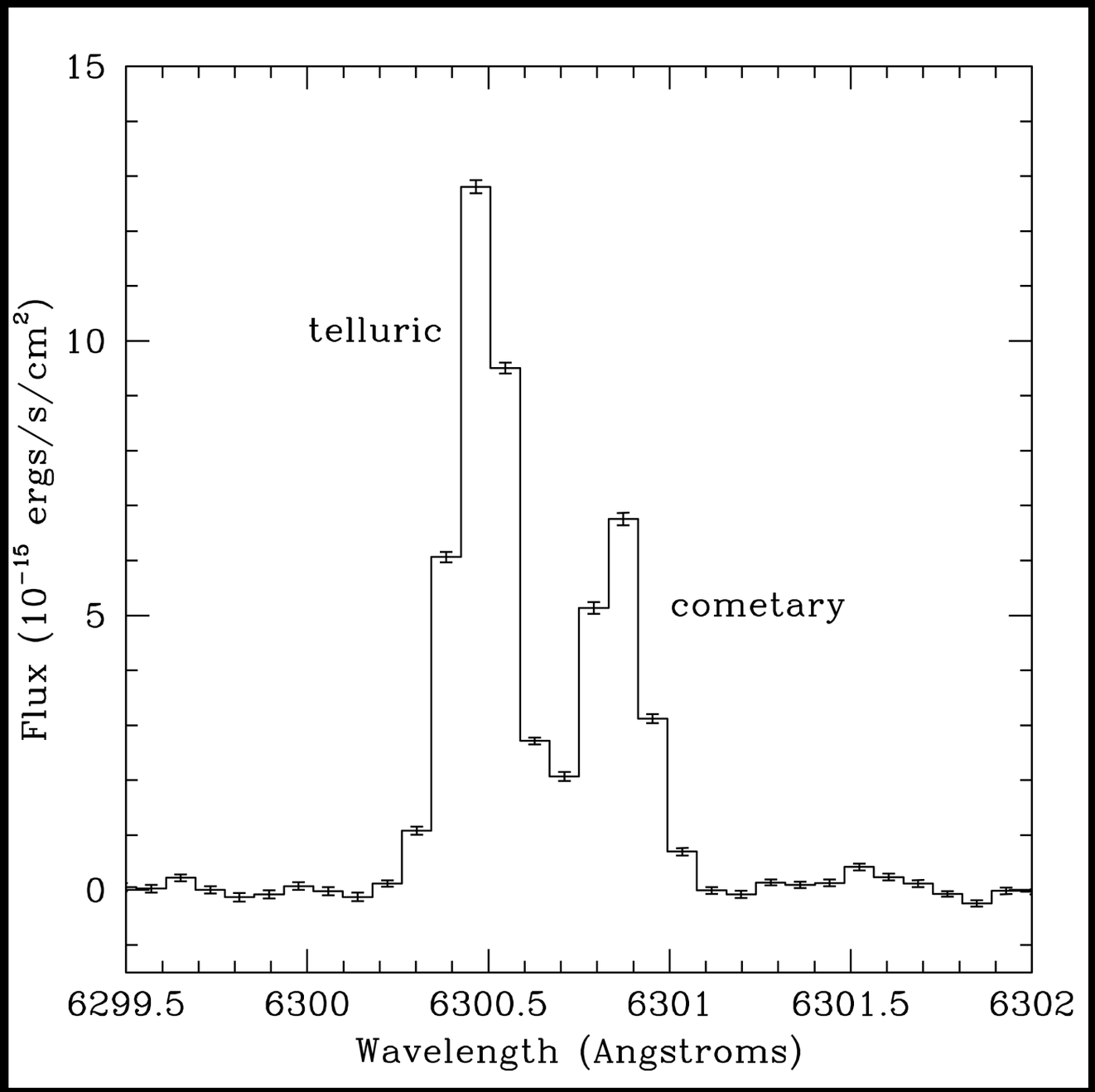
- iSHELL on the NASA IRTF
- UT January 30, 2018
- R=2.8 AU
- R≡$\lambda/\Delta\lambda$=40,000

Image Credit: NASA IRTF

ISHELL IRTF-CO



[OI]6300 FROM APACHE POINT



- APO ARCES, same night as iSHELL observations
- $R \equiv \lambda/\Delta\lambda = 30{,}000$
- Usually a pretty reliable tracer of H_2O, but requires H_2O to be the dominant oxygen-bearing species